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THE MEASUREMENT AND EVALUATION OF THE LARGE AGRICULTURAL TRACTOR OPERATOR'S WHOLE–BODY VIBRATION FOR FOUR TYPES OF LAND AND TWO RUNNING SPEEDS

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Abstract: The whole–body vibration is a significant physical risk factor for drivers associated with low back pain and their comfort while driving on different types of terrain. Whole–body vibration levels were measured on several types of agricultural tractors during a wide range of normal field operations. In this study, we outline a system for measuring the WBV operator of agricultural tractors of different types, with loads on several types of terrain and different speeds. to assess the risks to the human body according to ISO standards. The evaluation of the driver's exposure to vibration on 4 types of terrain, running at 2 different types of speed and a value of the seat suspension angle for an agricultural tractor of 80 HP and 2500 RPM, being a large tractor consisted in the installation of 3 triaxial accelerometers at the operator–seat interface, on the seat–back at the level of the spine and on the tractor cab near the operator's support leg, in accordance with ISO 2631–1. The data collected were calculated and evaluated using VATS NexGen Ergonomics software in accordance with ISO 2631–1.
Keywords: WBV, aRMS, Exposure, agricultural tractor, ride comfort, speed drive, VATS

1. INTRODUCTION

Nowadays, research trends for the safety and comfort issues of large agricultural tractor operators are reviewed and tested according to specialized standards on operator exposure to whole–body vibration during tasks. Agricultural tractors are widely used on off–road terrain: plowed land, uneven ground, uncultivated land and straight land, for various operations. Heavy vehicle drivers are known to be exposed to high vibration levels throughout their bodies (WBV) when driving on different types of terrain depending on their specificity *(Shaha et al., 2017)*. WBV exposure occurs mainly in sitting positions while driving. WBV is usually transmitted through the human body when it is in contact with vibrating surfaces (i.e. the driver's seat, the seat back or the floor of the vehicle). Adverse effects that occur due to exposure to vibration are low back pain, musculoskeletal disorders *(Scarlett et al., 2017; Goering, et al., 2013; Rauser and Williams, 2014; Basri and Griffin, 2013; Kim et al., 2016)* fatigue and discomfort. Cross–sectional studies have reported that the prevalence of back pain among drivers for exposure to vibration is high – tractor drivers (81%) *(Aisyah et al., 2017)*. EU–based European Union Directive 2002/22 / EU im; posed limits on vibration exposure, and ISO 2631–1: 1997 (*International Organization for Standardization, 1997)* set a WBV daily limit of 1.15 m/s^2 and an action level of 0.5 m/s^2 for a daily exposure period equivalent to eight hours. The latest research in the field has focused on the study of the effects of vibrations on the human body and their influence on the driver's health, describing minimum measurement protocols on different types of roads *(Debolia et al., 2017; Kyuhyun et al., 2017; Cutini et al., 2016)* at different speeds of the tractor, using triaxial accelerometers, measurements based on the indications of ISO 2631–1 being presented in articles *(Oncescu and Petcu, 2021; Oncescu et al., 2021)*.

2. MATERIALS AND METHODS – EXPERIMENTAL PROTOCOL

To evaluate the vertical vibrations transmitted to the driver, experimental tests were performed using a TD80D large tractor, with its technical specifications shown in Table 1. Figure 1 shows the 4 types of terrain used at the experimental site, National Institute of Agricultural Machinery in Bucharest. Figure 1 shows the 4 types of terrain used in the experimental protocol for WBV measurement.

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Table 1. Specifications of tractor used for WBV evaluation

Item	Specifications
Model	TD80D – New Holland
Power/Kw	80
Traction	MFWD
Size [mm]	3510 (L) / 2620 (H) / 2000 (W)
Suspension system	Adjustable suspension seat (without axle or cab suspension)
Front tire pressure/kPa	340
Rear tire pressure/kPa	420

Figure 1 – Performing experimental tests on terrain types according to the experimental protocol, at speeds of 6 and 12 km/h: a) straight terrain; b) uncultivated land; c) uneven ground; d) plowed land

A qualified operator (weight=70 kg and height=180 cm) performed all field tests, which were performed in June, with an average temperature of 25 ° C and air humidity of 50%. He voluntarily participated in the experimental measurements after signing an informed consent, holding a driving license and being medically fit.

The experimental protocol describes the location of the experimental tests, the type of vehicle used (Table 1), the types of terrain (Figure 1), the speed on the road and the value of the suspension's height of the tractor's seat. Experimental measurements were made at speeds of 5 km/h and 10 km/h, taking into account the factors influencing the transmission and perception of vibrations by the driver, the suspension of the tractor's seat being adjusted to the maximum height with the suspension angle of 10°, and the position of the driver being at a right angle, 90º in relation to the inclination of the seat back.

The equipment used to measure the whole–body vibration of a driver sitting in a seat is the Vibrations Analysis Tool Set (VATS), developed by Nex Gen Ergonomics *(VATS™, http://www.nexgenergo.com/ergonomics/vats.html).* VATS software is based on ISO2631–1 which describes procedures for evaluating whole–body vibration.

The equipment includes the MWX8 Data LOG device, which is a fully portable, programmable data acquisition unit of the Biometrics system *(User Manual, Biometrics Ltd, http://www.biometricsltd.com).* This is a system of portable sensors, used for the acquisition and processing of biomechanical data *(Tarnita, 2016; Tarnita and Oncescu, 2020)* in various fields of research, such as: biomechanics, clinical medicine, rehabilitation, sports performance and ergonomics *(Gherman et al., 2019; Tarnita et al., 2019; Geonea and Tarnita, 2017; Tarnita et al., 2016; Vaida et al., 2020; Tarnita et al., 2014).*

Accelerations along the three perpendicular axes (a_x, a_y, a_z) were measured simultaneously using 3 tri–axial accelerometers. These measurements were performed both on the seat, on the seat–back and on the cab floor. The accelerations were weighted in frequency using the W_k and W_d weight curves, obtaining the values of the root mean square accelerations (RMS) a_{wx}, a_{wy} and a_{wz} along the individual axes, as described in ISO 2631–1.

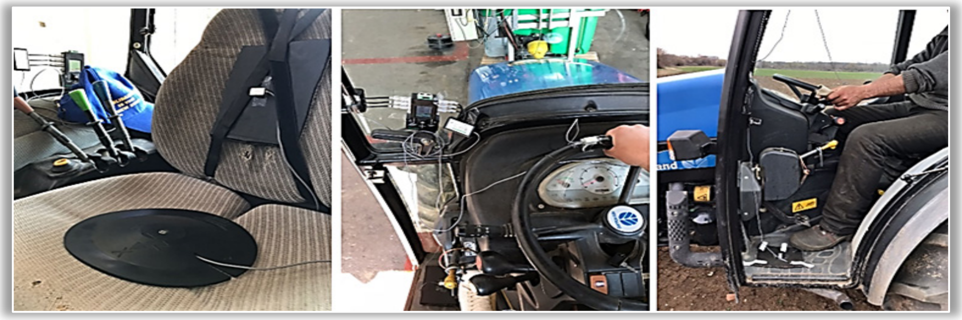

Figure 2 – Installing triaxial accelerometers on the surface of the tractor's seat, on the seat–back and on the cab floor at the support leg

3. RESULTS

According to ISO 2631–1, an analysis of the driver is done through the whole body vibrations determined during the eight experimental tests. The root mean square (aRMS) produces a value that represents the average vibration exposure adjusted to represent the workload, while VDV represents the cumulative vibration exposure during the experimental test.

The accelerations of the tractor cab seat, backrest and floor weighted according to the frequency of the levels found on the 4 different road surfaces in the vertical direction of the Z axis of measurement, are shown in the following figures. WBV emission levels were found to increase in proportion to the vehicle's running speed and road roughness, and the growth rate was higher on dirt land, while lower exposures were found on the paved road.

Figures 3, 4, 5 and 6 show the graphical representation of the data collected by the 3 ACLs installed on the seat surface, the seat back and the driver's legs, as well as the corresponding aRMS graphs, on the Z axis for the seat back comfort zone, on the 4 terrain types for the speeds set in the protocol of 5 km h and 10 km/h.

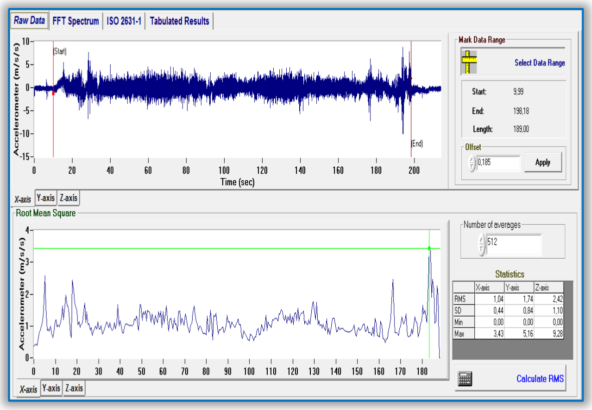

Figure 3 – Representation of the aRMS weighted acceleration's value for the entire measurement period for straight road with a speed of 10 km/h, rendered by the VATS software

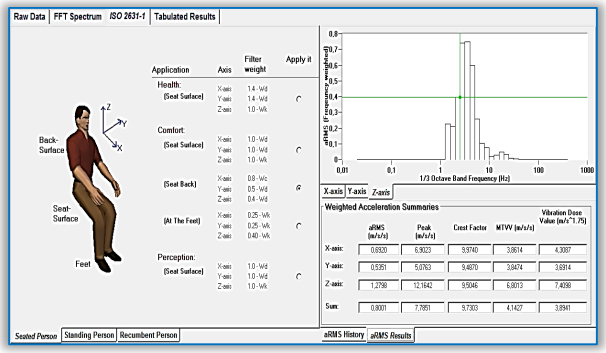

Figure 4 – Raw data and aRMS, collected on a straight road at a speed of 10 km/h, by the ACL for the Seat Back comfort zone, rendered by VATS software

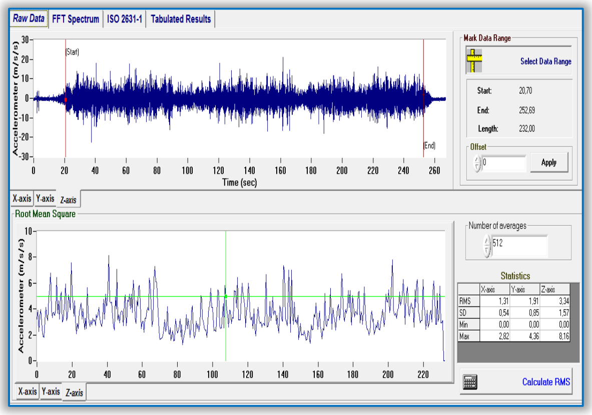

Figure 5 – Representation of the value of the aRMS weighted acceleration for the entire measurement period for the unsealed road at a speed of 10 km/h, rendered by the VATS software

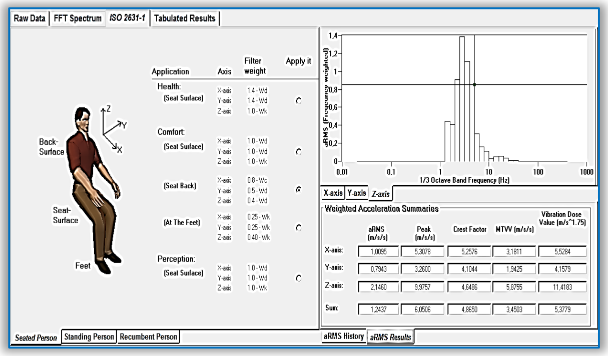

Figure 6 – Raw data and aRMS, collected on unsealed road at a speed of 10 km/h, by the ACL for the Seat Back comfort zone

Diagrams, graphs and similar tables of weighted acceleration values and aRMS peaks are obtained for all eight sets of experimental tests, tables 2, 3, 4 and 5 show the aRMS values and peak values of the vibration accelerations transmitted for the two cases.

For all eight sets of experimental tests, diagrams, graphs and similar tables of aRMS weighted acceleration values are obtained, so that the following diagrams show the aRMS values of vibration accelerations transmitted to the 3 ACL sensors, for the 4 road types, at both speeds of the tractor of 5 km/h, respectively 10 km/h.

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Table 2. Values of aRMS and peaks of vibration for Case I Straight road at a speed of 5 km/h and 10 km/h

Cases	Position of accelerometer	Axis	aRMS [m/s/s]	Peak [m/s/s]
Case I. 1. Straight road at a speed of 5 km/h	Seat surface	X–axis	0.2369	1.7503
		Y–axis	0.3981	2.2381
		Z–axis	1.0148	9.4047
		Sum	1.1155	9.8245
	Seat back	X–axis	0.3754	3.1834
		Y–axis	0.3981	2.2381
		Z–axis	0.6374	4.5913
		Sum	0.4414	3.3333
	At the Feet	X–axis	0.3698	3.1797
		Y–axis	0.7002	3.5553
		Z–axis	1.0148	9.4047
		Sum	0.4516	3.9463
Case I. 2. Straight road at a speed of 10 km/h	Seat surface	X–axis	0.3935	3.4512
		Y–axis	0.5351	5.0763
		Z–axis	2.1152	21.970
		Sum	2.217	22.812
	Seat back	X–axis	0.6921	6.9023
		Y–axis	0.5351	5.0763
		Z–axis	1.2798	12.164
		Sum	0.8001	7.7851
	At the Feet	X–axis	0.7112	3.5670
		Y–axis	0.8662	4.9615
		Z–axis	1.1152	2.1970
		Sum	0.8913	3.1256

Table 3. Values of aRMS and peaks of vibration for Case II Uncultivated land at a speed of 5 km/h and 10 km/h

Cases	Position of accelerometer	Axis	aRMS [m/s/s]	Peak [m/s/s]
Case II. 1. Unprocessed road at a speed of 5 km/h	Seat surface	X–axis	0.3972	1.8743
		Y–axis	0.7299	3.2958
		Z–axis	1.5995	9.7027
		Sum	1.8025	10.414
	Seat back	X–axis	0.5894	2.9119
		Y–axis	0.7299	3.2958
		Z–axis	1.1736	5.1419
		Sum	0.7589	3.5175
	At the Feet	X–axis	0.5261	2.692
		Y–axis	0.8452	4.1426
		Z–axis	1.5995	9.7027
		Sum	0.6865	4.0729
Case II. 2. Unprocessed road at a speed of 10 km/h	Seat surface	X–axis	0.6116	2.8414
		Y–axis	0.7943	3.2600
		Z–axis	2.9931	17.321
		Sum	3.1565	17.853
	Seat back	X–axis	1.0095	5.3078
		Y–axis	0.7943	3.2600
		Z–axis	2.146	9.9757
		Sum	1.2437	6.0506
	At the Feet	X–axis	0.9718	6.0580
		Y–axis	0.9823	6.5366
		Z–axis	1.0987	7.6554
		Sum	1.2461	7.2780

Table 4. Values of aRMS and peaks of vibration for Case III Uneven road at a speed of 5 km/h and 10 km/h

Cases	Position of accelerometer	Axis	aRMS [m/s/s]	Peak [m/s/s]
Case III. 1. Uneven road at a speed of 5 km/h	Seat surface	X–axis	0,4404	2,8686
		Y–axis	0,7035	3,6031
		Z–axis	1,5481	11,693
		Sum	1,7566	12,568
	Seat back	X–axis	0,6156	4,0377
		Y–axis	0,7073	3,6031
		Z–axis	1,237	6,6342
		Sum	0,7817	4,5521
	At the Feet	X–axis	0,5287	3,2536
		Y–axis	0,8197	5,0664
		Z–axis	1,5481	11,693
		Sum	0,6655	4,9137
Case III. 2. Uneven road at a speed of 10 km/h	Seat surface	X–axis	0,5185	2,8686
		Y–axis	0,7073	3,0172
		Z–axis	1,9722	13,408
		Sum	2,1584	14,039
	Seat back	X–axis	0,7436	4,9810
		Y–axis	0,7073	3,0172
		Z–axis	1,7191	9,6434
		Sum	0,9756	5,7475
	At the Feet	X–axis	0,6386	4,6703
		Y–axis	0,8324	4,4081
		Z–axis	1,9722	13,408
		Sum	0,8313	5,5985

Table 5. Values of aRMS and peaks of vibration for Case IV Arable land at a speed of 5 km/h and 10 km/h

Cases	Position of accelerometer	Axis	aRMS [m/s/s]	Peak [m/s/s]
Case IV. 1. Arable land at a speed of 5 km/h	Seat surface	X–axis	0,582	3,6023
		Y–axis	0,949	4,8609
		Z–axis	0,7929	6,4265
		Sum	1,3667	8,8264
	Seat back	X–axis	0,6663	3,9778
		Y–axis	0,949	4,8609
		Z–axis	0,7678	5,4683
		Sum	0,7768	4,5627
	At the Feet	X–axis	0,4408	3,5758
		Y–axis	0,6348	3,9232
		Z–axis	0,7929	6,4265
		Sum	0,3714	2,8929
Case IV. 2. Arable land at a speed of 10 km/h	Seat surface	X–axis	0,6698	6,0801
		Y–axis	1,0208	4,1169
		Z–axis	1,4135	9,4200
		Sum	1,8678	11,944
	Seat back	X–axis	0,8306	7,9160
		Y–axis	1,0208	4,1169
		Z–axis	1,3328	6,6778
		Sum	0,9931	7,1749
	At the Feet	X–axis	0,5985	5,7183
		Y–axis	0,7384	3,5868
		Z–axis	1,4135	9,4200
		Sum	0,6133	4,1286

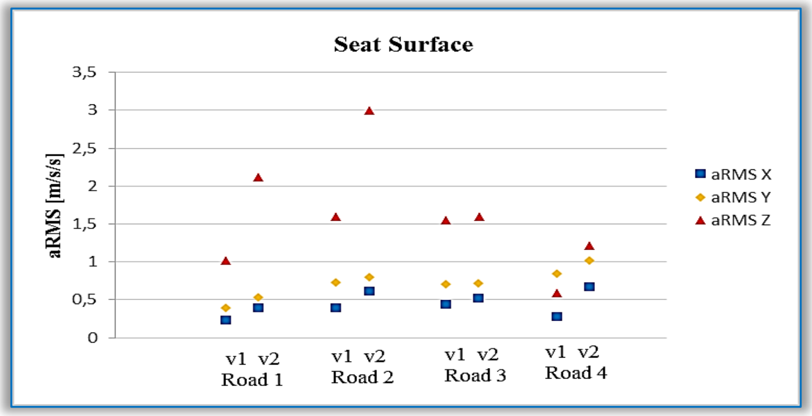

Figure 7 – Graphical representation of the aRMS value for the 4 types of roads at speeds of 5 km/h and 10 km/h, for the ACL at the seat surface

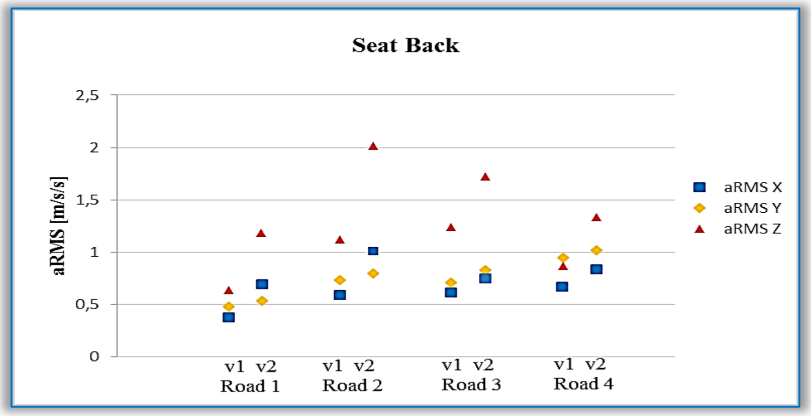

Figure 8 – Graphical representation of the aRMS value for the 4 types of roads at speeds of 5 km/h and 10 km/h, for the rear ACL

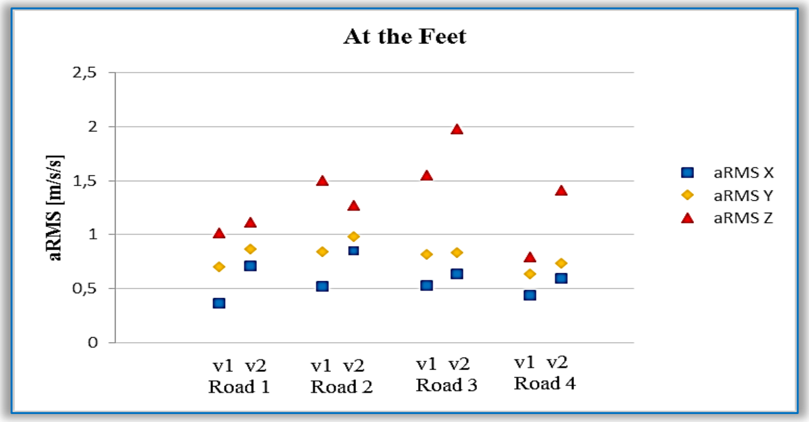

Figure 9 – Graphical representation of the aRMS value for the 4 types of roads at speeds of 5 km/h and 10 km/h, for the support leg ACL

4. DISCUSSION

By comparing the results obtained for the four types of roads at the traffic speeds described in the experimental protocol, we obtained the graphical representation of the aRMS acceleration values corresponding to the three triaxial vibration measuring accelerometers used for the analysis and the impact of increasing vibration amplitudes on the driver while driving a large tractor.

The diagrams in figures 7–13 were created based on the plotted results of the values in tables 2, 3, 4 and 5. In figures 3, 4, 5, 6, it was shown that the type of road and the running speed had significant effects on weighted RMS. The weighted RMS values increased with the increasing speed, and this trend was noticed more on rough terrain, due to unevenness specific to the road / terrain category (comparison between straight road and rough road at a speed of 10 km/h).

Taking into account the road category and the running speed for the 3 mounted sensors, it can be seen in figure 10, that the highest aRMS value is the one recorded in the direction of the Z axis of measurement with ACL Seat Surface, reaching the value of 2.9931 m/s^2, on rough terrain at a speed of 10 km/h, and the lowest value recorded in the direction of the Z axis of measurement is the value of 0.6678 m/s^2 measured with ACL Seat Back, on the plowed land at a speed of 5 km/h.

Based on the processed experimental data collected during the eight tests, the aRMS values corresponding to the three accelerometers and the three coordinate axes for each accelerometer, the comfort of the tractor's driver can be analyzed. As for the precautionary area for health orientation, it increases with speed being influenced by the nature of the terrain types. The authors of the articles *(Kabir et al., 2014; Scarletta et al., 2007)* reached similar conclusions.

Thus, in this article, for the straight road, at a speed of 5 km/h, the result was an aRMS value in the direction of the Z axis for the rear ACL, equal to 0.63 m/s^2, very close to the similar value in Article *(Kabir et al., 2014)* between 0.47 and 0.62 m/s^2. In the direction of the X–axis for the plowed land, the aRMS values for the 3 ACLs at a speed of 5 km/h are between [0.44 – 0.66 m/s^2] close to the similar value in Article *(Kabir et al., 2014)* equal to 0.5 m/s^2. Also in Article *(Scarletta, et al., 2007)* the maximum values of aRMS reached on a straight road at a speed of 10 km/h, for the ACL for the rear and the foot, respectively the floor of the tractor cab, on each axis of measurement X=0.75 m/s^2, Y=1 m/s^2 and Z=0.75 m/s^2, are close to the values obtained in this article for the respective case, namely, X = 0.71 m/s^2, Y=0.86 m/s^2 and Z=0 .91 m/s^2.

Tabel 6. The state of comfort of the human body subjected to vibrations. *(International Organization for Standardization, 1997)*

Type of road	Position of accelerometers	Speed [km/h]	Range of values obtained	Condition STAS 2631–1	Description
Straight road	Seat Surface	5 km/h	0.23 m/s^2 – 0.39 m/s^2	0.315 m/s^2 – 0.63 m/s^2	A little uncomfortable
		10 km/h	0.39 m/s^2 – 0.53 m/s^2	0.315 m/s^2 – 0.63 m/s^2	A little uncomfortable
	Seat Back	5 km/h	0.37 m/s^2 – 0.39 m/s^2	0.315 m/s^2 – 0.63 m/s^2	A little uncomfortable
		10 km/h	0.53 m/s^2 – 0.63 m/s^2	0.315 m/s^2 – 0.63 m/s^2	A little uncomfortable
	Feet	5 km/h	0.36 m/s^2 – 0.70 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.71 m/s^2 – 0.81 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
Unprocessed road	Seat Surface	5 km/h	0.39 m/s^2 – 0.72 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.61 m/s^2 – 0.79 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
	Seat Back	5 km/h	0.58 m/s^2 – 0.72 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.79 m/s^2 – 1 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
	Feet	5 km/h	0.52 m/s^2 – 0.84 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.97 m/s^2 – 0.98 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
Uneven road	Seat Surface	5 km/h	0.44 m/s^2 – 0.70 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.51 m/s^2 – 0.70 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
	Seat Back	5 km/h	0.61 m/s^2 – 0.70 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.70 m/s^2 – 0.74 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
	Feet	5 km/h	0.52 m/s^2 – 0.81 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.53 m/s^2 – 0.93 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
Arable land	Seat Surface	5 km/h	0.58 m/s^2 – 0.94 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.66 m/s^2 – 1 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
	Seat Back	5 km/h	0.66 m/s^2 – 0.94 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.83 m/s^2 – 1 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
	Feet	5 km/h	0.44 m/s^2 – 0.63 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable
		10 km/h	0.59 m/s^2 – 0.73 m/s^2	0.5 m/s^2 – 1 m/s^2	Fairly uncomfortable

Following the analysis of the obtained graphs, in relation to the weighted frequency for the comfort reactions of the human body in vibration environments, for the experimental tests performed on the four types of roads, the driver's comfort is quite low, presenting an increase in the value of the aRMS acceleration depending on the road category and an increase in driving speed, which makes the comfort reaction almost intolerable, so the driver is exposed to a high level of vibration, posing a significant health and safety risk.

For the comfort state of the human body subjected to vibrations on the four categories of roads and the two speeds analyzed, for the 3 sensors installed on the surface of the seat, backrest and legs, the following characteristics are presented in table 6.

5. CONCLUSION

The evaluation of human responses to whole–body vibration was obtained by direct measurements on the tractor seat, respectively the tractor cab floor and the seat–back in real operating conditions, according to the experimental protocol and the standard method of collecting vibrations using the 3 ACL sensors (ISO 2631–1).

The raw data were then applied to the vibration analysis toolkit (VATS) and analyzed according to the vibration standard. Vibration data were analyzed for comfort on the seat surface of the back and leg area for each participant in the experimental tests.

The results of the analysis presented in this article, concerning human responses to whole–body vibrations, allow the analysis of the effects that occur during driving the tractor on different roads and at different speeds, so that the influence of Root–Mean–Square vibration acceleration values (aRMS) presented in the experimental cases is significant for the evolution of the driver's state of health in terms of the values achieved in the normal mode of operation of the tractor on arable, uneven and uncultivated land as opposed to straight road due to a significant increase in vibration intensity depending on the increase in traffic speed.

References

[1] Shaha, M.D., Kabir, N., Chung, S.O., Yong–Joo, K., Nam–Seok, S. ,Soon–Jun, H., Measurement and evaluation of whole body vibration of agricultural tractor operator, Int J Agric & Biol Eng, Vol. 10, No.1, 2017.
[2] Scarlett A. J, Price J S, Stayner R M. Whole–body vibration: Evaluation of emission and exposure levels arising from agricultural tractors. Journal of Terramechanics, 2017; 44: 65–73.
[3] Goering, C.E., Stone,M.L., Smith, D.W., Turnquist P K. Human factors and safety. Chapter 15 in Off–Road Vehicle Engineering Principles. 2013. ASAE, St. Joseph, MI. pp 421–462.
[4] Rauser, E.S.C., Williams, J., 2014. Trucking Industry: Examining Injuries for Prevention, 2006–2012. Washington State Department of Labor & Industries.
[5] Basri, B., Griffin, M.J., 2013. Predicting discomfort from whole–body vertical vibra– tion when sitting with an inclined backrest. Appl. Ergon. 44 (3), 423–434.
[6] Kim, J.H., Zigman, M., Aulck, L.S., Ibbotson, J.A., Dennerlein, J.T., Johnson, P.W., 2016.Whole body vibration exposures and health status among professional truck drivers: across–sectional analysis, vol. 60 (8).
[7] Aisyah, S. A. and Nawal, A., Abdul, J., Vertical Suspension Seat Transmissibility and SEAT Values for Seated Person Exposed to Whole–body Vibration in Agricultural Tractor Preliminary Study, Procedia Engineering 170, 435–442, 2017.
[8] International Organization for Standardization, 1997. International Standard 2631 1: 1997 Mechanical Vibration and Shock–evaluation of Human Exposure to Whole–Body Vibration. Part 1: General Requirements.
[9] Debolia, R., Calvoab, A., Pretia, C., Whole–body vibration: Measurement of horizontal and vertical transmissibility of an agricultural tractor seat, IJIE, Vol. 58, pp. 69–78, 2017.
[10] Kyuhyun Sima, Hwayoung Leea, Ji WonYoonb Chanho Choib Sung–HoHwang, Effectiveness evaluation of hydro–pneumatic and semi–active cab suspension for the improvement of ride comfort of agricultural tractors, Journal of Terramechanics, Volume 69, Pages 23–32, 2017.
[11] Cutini et al., M. Cutini, C. Costa, C. Bisaglia, Development of a simplified method for evaluating agricultural tractor's operator whole body vibration, J. Terramech., 63, pp. 23–32, 2016.
[12] Oncescu T.A., Petcu A., Experimental study of the influence of road surface and car speed on the whole body vibrations, 1st International Conference on Advanced Research in Engineering, vol.1, pp:115–120, CARE.
[13] Oncescu,T.A., Petcu, A., Tarniţă D., Evaluation of Whole–Body Vibrations and Comfort State of Tractor Driver for Different Types of Terrain and Speeds, Acta Technica Napocensis, Applied Mathematics, Mechanics, and Engineering, vol. 64 (1), 2021
[14] VATS™ (Vibration Analysis Tool Set), http://www.nexgenergo.com/ergonomics/vats.html
[15] User Manual, Biometrics Ltd, http://www.biometricsltd.com
[16] Tarnita, D., Wearable sensors used for human gait analysis, Rom J Morphol Embryol, 57(2), pp 373–382, 2016.
[17] Tarnita, D., Oncescu, T.A., Sensors Used for Human Gait Monitoring, 30 TH SIAR International Congress of Automotive and Transport Engineering: Science and Management of Automotive and Transportation Engineering, pp. 518–524, 2020.
[18] Gherman, B., Birlescu, I., PLITEA, N., et al., On the singularity–free workspace of a parallel robot for lower–limb rehabilitation, Proceedings of the Romanian Academy, Vol. 20, Nr. 4, pp. 383–391, 2019.

[19] Tarnita, D., Pisla, D., Geonea, I., et al., Static and Dynamic Analysis of Osteoarthritic and Orthotic Human Knee, J Bionic Eng, 16, pp. 514–525, 2019.
[20] Geonea, I., Tarnita, D., Design and evaluation of a new exoskeleton for gait rehabilitation, Mechanical Sciences, 8(2), pp 307–322. 2017
[21] Tarnita, D., Catana, M., Dumitru, N., Tarnita, D.N., Design and Simulation of an Orthotic Device for Patients with Osteoarthritis. New Trends in Medical and Service Robots, Springer Publishing House, pp. 61–77, 2016.
[22] Vaida, C., I. Birlescu, A Pisla, I. Ulinici, D. Tarnita, G. Carbone, D. Pisla., Systematic Design of a Parallel Robotic System for Lower Limb Rehabilitation, in IEEE Access, vol. 8, pp. 34522–34537, 2020.
[23] Tarnita, D., M. Catana, DN Tarnita, Contributions on the modeling and simulation of the human knee joint with applications to the robotic structures, In "New Trends on Medical and Service Robotics: Challenges and Solutions", Mechanisms and Machine Science 20, pp. 283–297, Springer Verlag, 2014.
[24] Kabir, M.S., Ryu, M.J., Chung, S.O., Kim, Y.J., Choi, C.H., Hong, S.J., et al. Research trends for performance, safety, and comfort evaluation of agricultural tractors: A review.Journal of Biosystems Engineering, vol. 39(1), pp. 21–33, 2014.
[25] Scarletta, A.J., Pricea, J.S. Stayner, R.M., Whole–body vibration: Evaluation of emission and exposure levels arising from agricultural tractors, Journal of Terramechanics, Volume 44, Issue 1, January 2007, pp. 65–73.

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